# Assessment of Background Scattering at X- and Ku-band in Snow Remote Sensing


Shurun Tan [1], Do-Hyuk Kang [2], Jiyue Zhu [1], Weihui Gu [1], Liuxi Tian [3], and Leung Tsang [1]

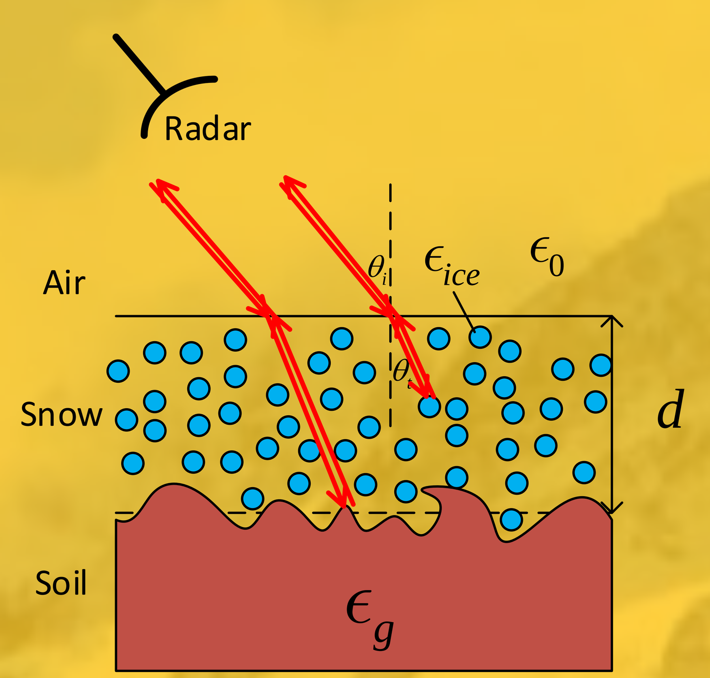
[1] Radiation Laboratory, Department of EECS, University of Michigan, Ann Arbor, MI, USA

[2] NASA Goddard Space Flight Center (GSFC), Greenbelt, MD, USA

[3] Department of Geological Science, University of Texas at San Antonio, TX, USA

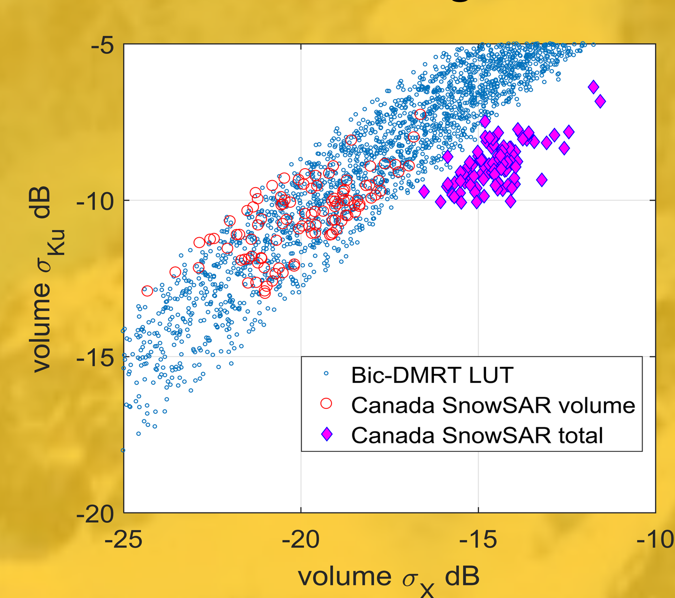
EECS RadLab


## Why Care about Snowpack Background Scattering? -- A look at the SnowSAR Data at Trail Valley Creek, Canada, 2012/13



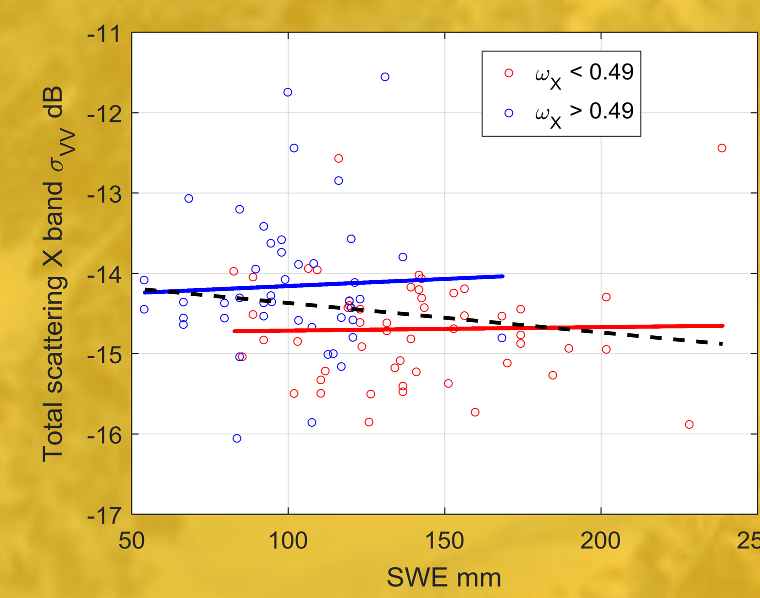

$$\sigma_{VV}^{total} = \sigma_{VV}^{bg}\exp\left(-2\tau\sec\theta_t\right)+\sigma_{VV}^{vol}$$

SnowSAR data against LUT



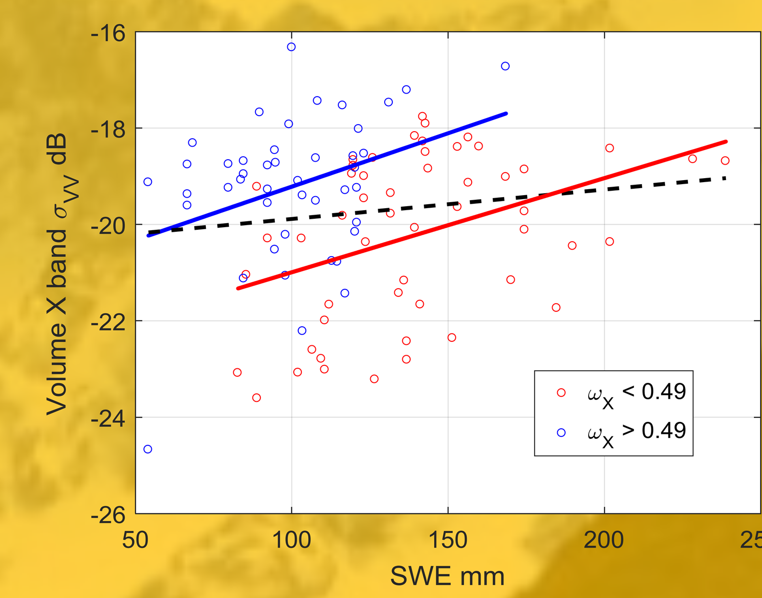

- Background scattering affects more at X- than Ku- band
- Good volume scattering prediction through Bicontinuous media / DMRT.

Total backscatter vs. SWE




- Classification of backscatter through equivalent grain size (represented by albedo) improves its sensitivity to SWE

Volume backscatter vs. SWE

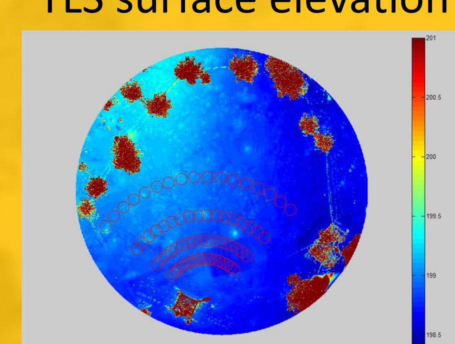



- Subtraction of background scattering further restores the high sensitivity of backscatter to SWE

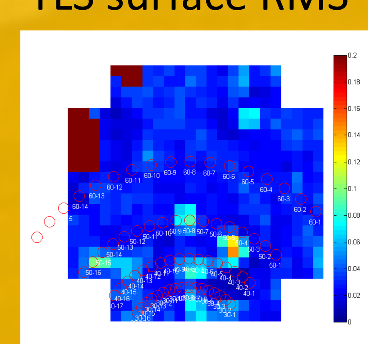
## Field Observations for Snowpack/ Soil Interface Characterization

### Soil Moisture, Roughness and Temp. Characterization

TLS surface elevation



TLS surface RMS

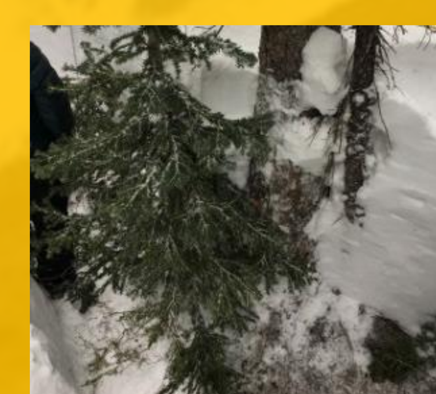


(TLS plots courtesy of FMI)

- Soil moisture: wet weight, dry weight; Hydro Probe
- Soil roughness:
  - Pin board: difficult to clean snow, better done at snow free condition; ~0.8cm RMS
  - Terrestrial lidar scan: snow free condition; influenced by small scale surface vegetation; ~2cm RMS

### Snow-buried Vegetation Characterization

- Geometries
- Orientations
- Number Densities
- Moisture Content and Permittivities



Trees and shrubs

Deadfall with branches

Organic layer with mosses/ liches

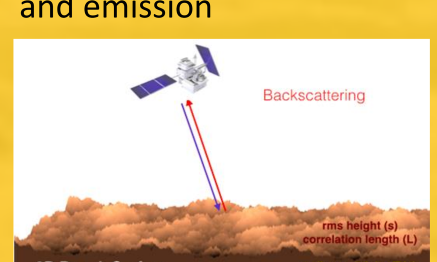
Grass

## Modeling of Background Scattering from Snow/ Soil Interface

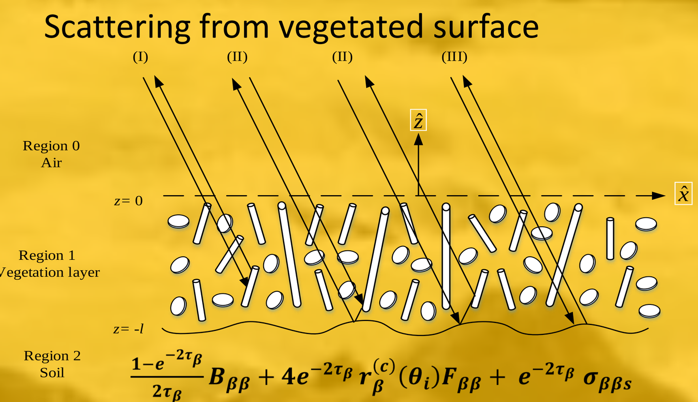
**Surface Scattering from the Snow/Soil Rough Interface:**

- Method 1: Use empirical Model, such as OH model
  - Two parameters: rms and $\varepsilon_g$
- Method 2: Use physical scattering model of NMM3D
  - Three parameters: rms, correlation length (cl), and $\varepsilon_g$
  - Applicable to wide range of surface parameters

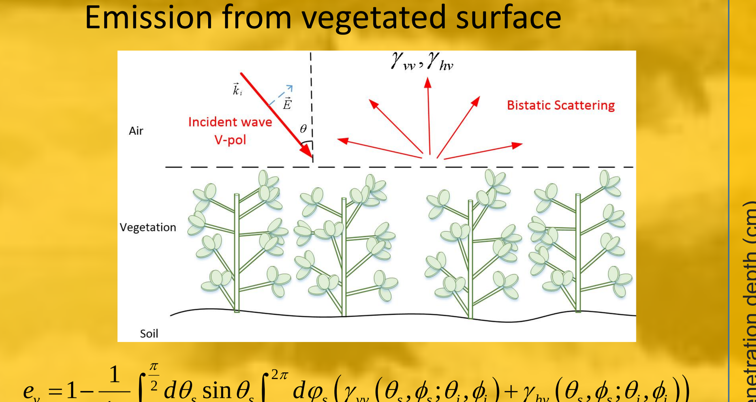
Rough surface scattering and emission




Scattering from vegetated surface



Emission from vegetated surface

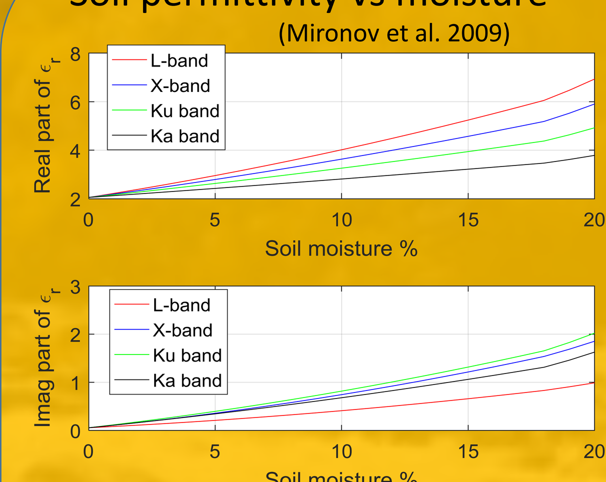


**Volume Scattering from Buried Vegetation:**

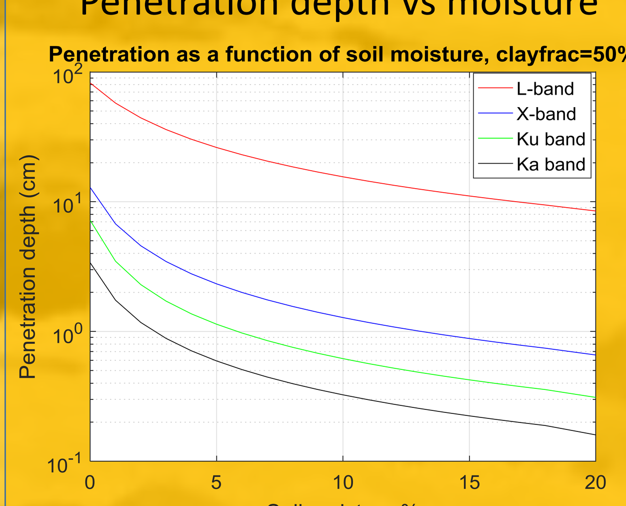
- Method 1: Distorted Born Approximation
- Method 2: Radiative Transfer with Multiple Scattering
- Method 3: Layered roughness model for the decayed organic layer

Soil permittivity vs moisture

(Mironov et al. 2009)

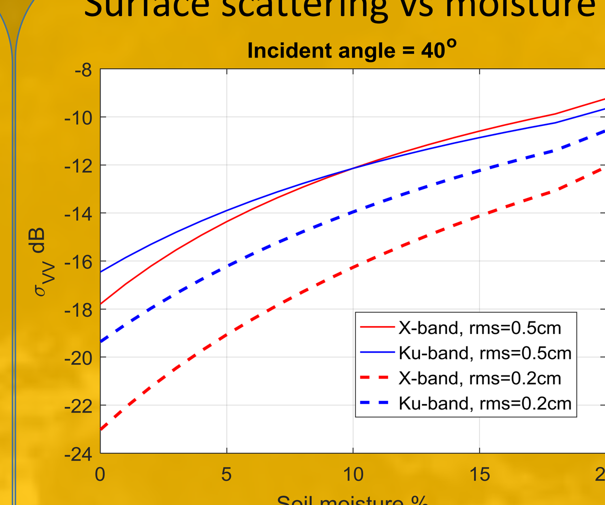



Penetration depth vs moisture



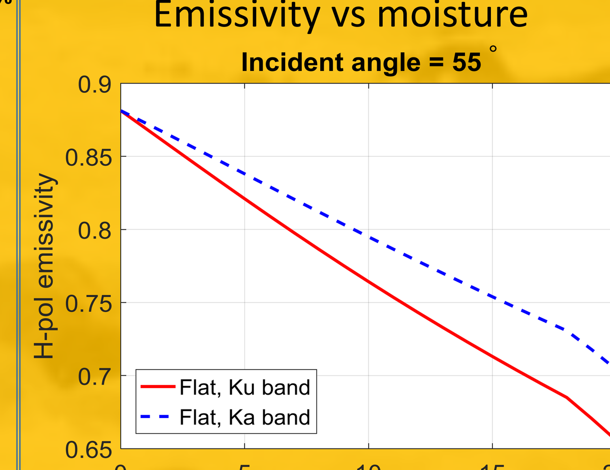

L-band (1.5GHz), X-band (9.6GHz), Ku-band (17.2GHz), Ka-band (36.5GHz)

Surface scattering vs moisture



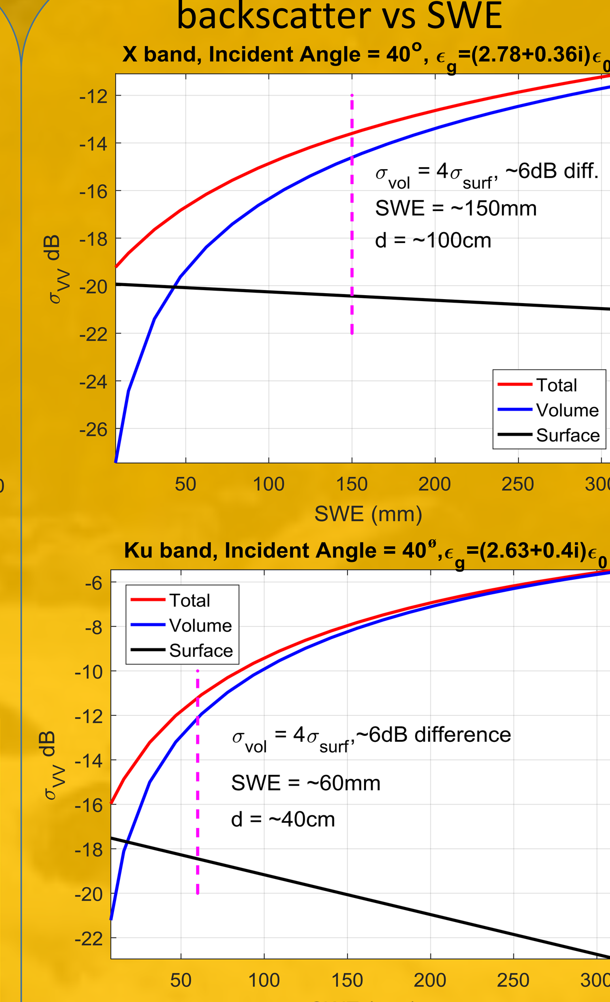

X-band (9.6GHz), Ku-band (17.2GHz) OH model

Emissivity vs moisture




Ku-band (18.7GHz), Ka-band (36.5GHz)

backscatter vs SWE




X-band (10.2GHz), Ku-band (17.2GHz)

Snow:Bicontinuous / DMRT

$f_v = 0.1685, b = 1.2, \langle\zeta\rangle = 10000$

Surface scattering: OH

cl/rms = 10, rms = 0.3cm

Moisture: 5%

## Estimation of Background Scattering in the SWE Retrieval Algorithm

- Method 1: Polarimetry: volume / surface scattering decomposition
  - Option 1: requires fully polarimetry
  - Option 2: neglect double bounce term in snow scattering use only VV and VH
- Method 2: Combine Active and Passive
  - Snowpack: $\omega$ and $\tau$; temperature $T_s$ for passive
  - Surface: rms and $\varepsilon_g$; temperature $T_g$ for passive
  - Observables: $\sigma_X$, $\sigma_{Ku}$, $T_{b,Ku}$, $T_{b,Ka}$
- Method 3: snow free + snow on measurements
  - Option 1: Take snow free measurements as background scattering (time series)
  - Option 2: From snow free measurements derive rms (and cl), take $\varepsilon_g$ as a free variable to be determined in snow on condition; build conversion table w.r.t. snow density
- Require forward modeling with controlled ground measurements to check the accuracy of each approach